CHAPTER 23

CULVERTS

23.1 Waterway Openings

All matters concerning size of waterway openings shall be in liaison with the District's Water and Sewer Authority.

23.2 Hydraulic and Hydrologic Data

The following tabulation with complete information shall be shown on bridge plans and final bridge plans (see Table 23-A):

Table 23-A

HYDRAULIC AND HYDROLOGIC DATA		
DRAINAGE AREA (SQ. MI.)		
DESIGN DISCHARGE (FT^3)		
DESIGN WATER SURFACE ELEVATION (FT)		
ENERGY LINE ELEVATION (FT)		
FREQUENCY	50 YR.	100 YR.

23.3 General

For reinforced concrete box culverts, the horizontal joint between the walls and top slab shall be designated "Optional Construction Joint" when the height between the upper and lower horizontal joints is 8 ft. or less. The construction specifications provide that if the Contractor elects to omit the joint, he shall delay placing the concrete in the top slab for at least 2 hours after the concrete in the walls has been placed.

In addition, the joint between the invert slab and the sidewalls shall be detailed as a construction joint, and the invert slab concrete shall achieve a minimum compressive strength of 3000 psi prior to the construction of the remainder of the culvert.

Wingwall footings at their junction with the invert slab shall be detailed without a construction or contraction joint so that the footing concrete is placed monolithically with the invert slab.

Large storm drains (24 in. diameter or larger) shall not be discharged through walls of culverts in order to minimize adverse hydraulic characteristics.

The designer shall design and detail the culvert on the plans assuming cast-in-place concrete construction.

The Special Provisions for select projects (such as where staging is required or where limited construction time is essential to restore normal vehicular or rail traffic) may require precast culvert construction.

In such cases, the Structural Design Engineer shall select opening sizes for the cast in place concrete culvert that are obtainable in standard precast concrete sections. The designer shall contact various local precasters to obtain the latest information on standard precast culvert sizes that are commercially available.

Provisions for a low flow fish passage in the form of a fish trough or other means may be required for culverts in certain locations. The DDOT Project Manager will notify the designer of a need for a low flow fish trough during the permit review process prior to the development of the Final design.

In order to increase the inlet performance and for improved flow through the culvert, the bottom of inner top slab and walls edges shall be beveled as follows at the entrance of the culvert:

- For single cell box culverts, a 45-degree bevel of 1/2" per foot of culvert clear height shall be provided for the top slab and bottom edge of the culvert entrance. A 45-degree bevel of 1/2" per foot of culvert clear width shall be provided for both sidewalls and inside edges of the culvert waterway entrance.
- For twin cell box culverts, in addition to the bevels specified above, the center wall shall have a 45-degree of 2-1/2” on both sides. This is based on a minimum 8-inch wall thickness. For every 1-inch increase in the center wall thickness, there shall be a 1/2 inch increase of the bevel on both sides.

23.4 Design Criteria for Precast Reinforced Concrete Box Sections for Culverts

- Precast reinforced concrete box sections shall not be used where the top slab is to be used as a riding surface.
- Precast reinforced concrete box culverts shall be designed by the service load design method (allowable stress design) in accordance with Division 1, Section 17.7 of the **AASHTO Standard Specifications for Highway Bridges (including current Interims**).
- Live load shall conform to AASHTO HS25 or a tandem load, whichever produces the greatest stress.
- Dead load shall include 25 lbs/ft^2 for future application of a 2 in. thick wearing surface when the earth fill above the top of culvert is less than 2 ft.

- Headers, cut-off walls, wingwalls, footings and aprons shall be designed by the allowable stress design method in accordance with the AASHTO Standard Specifications for Highway Bridges (including current interims).
- Concrete for precast concrete elements shall have a minimum design compressive strength of $f'_c = 5000$ psi.
- The minimum concrete cover over the circumferential reinforcement shall be 1½ in. except on the exterior side of the top slab where it shall be 2 in.
- The wall thickness for precast culverts shall be a minimum of 8 in. The top and bottom slab thickness shall be a minimum of 10 in.
- A flexible watertight rubber gasket shall be provided at the joint between the precast units. The gasket shall be continuous around the circumference of the joints. Details of the transverse joint between the culvert sections shall be provided on the plans.
- A coarse aggregate layer shall be provided under the precast reinforced concrete box culvert sections. The depth of the coarse aggregate layer shall be a minimum of 24 in. It shall extend 12 in. on each side of precast reinforced concrete box culvert section.
- A waterstop shall be provided to prevent water from entering vertical joints between the end of precast culvert sections and any cast-in-place appurtenances such as wingwalls, cutoff walls, aprons and cast-in-place culvert end sections.
- Two rows of threaded inserts or bar extensions (longitudinal tie bolts) shall be provided in the end culvert section to facilitate the attachment of the culvert end section to the wingwalls. A detail of this connection shall be provided on the plans.
- As per item above, provide the same detail, if applicable, for the headwall attachment.
- If precast concrete units are used in parallel for multicell installations, the parallel units shall be placed a maximum of 6 in. apart. The 6 in. space between the units shall be filled in conformance with the Special Provisions. The purpose of this procedure is to ensure a positive means of lateral support between the parallel precast units.
- The use of precast concrete end sections, including headwalls, will be reviewed and approved on a culvert-by-culvert basis.
- However, precast end sections shall not be used when the skew angle requirements result in a situation where the short wall of a precast end section is less than 36 in. If approved for use, adequate provisions shall be made for cast in place appurtenances such as wingwalls, aprons and cutoff walls. The top mat of reinforcement, and ties, in the top slab shall be corrosion protected when the earth fill over the precast culvert is less than 24 in. The use of epoxy coated and galvanized reinforcement shall not be mixed.
- Lifting devices or holes will be permitted in each box section for the purpose of handling and erection. All lifting holes shall be filled with nonshrink grout, after the grout has cured, the area shall be coated with an epoxy waterproofing seal coat.
- Placement of precast units:

- The precast units shall be pulled against the prior installed section such that an adequate seal is obtained between the two connecting units and the rubber gasket.
- Prior to backfilling, a 24 in. wide strip of filter fabric shall be placed over the top and side transverse joints.
- To provide continuity and concrete shear transfer between the precast box sections, a longitudinal tie rod or prestressing strand shall be placed in position through a 1½ in. diameter hole.
- Four (4) longitudinal ties, one in each corner of the precast section, shall be provided.
- Longitudinal ties that are used to tie the precast units together shall be ¾ in. diameter high tensile strength steel bars conforming to AASHTO M275 (ASTM A722) or ½ in. 7 wire Grade 270 strands conforming to AASHTO M 203M (ASTM A416).
- No splices are permitted in the strands. Bars shall be galvanized in accordance in accordance with **AASHTO M 111.**
- End anchorages (nuts, washers and anchor plates) shall be compatible with the tie rod system and shall be galvanized in accordance with **AASHTO M 111**.
- The anchorages and end fittings for the ½ in. 7 wire strand and the corrosion protection method shall be detailed on the plans.
- Each tie rod shall be stressed to a tension of 30 kips.
- After tensioning, the exposed ends of the ties shall be removed so that no part of the ties, or of the end fittings, extends beyond a point 1 in. inside the anchorage pocket.
- All hardware associated with the end anchorage systems shall be galvanized. After tensioning has been completed the exposed parts of the end fittings shall be coated with two coats of bituminous paint.
- If hand holes are used for the installation of longitudinal ties, they shall be spaced appropriately.

- The precast reinforced concrete culvert units shall be manufactured in steel forms and steam cured in conformance with DDOT standards.
- Precast reinforced concrete culvert units shall not be shipped until 72 hours after fabrication and the 28-day compressive strength requirement is met.
- Precast reinforced concrete culvert units shall be given one coat of an epoxy waterproofing seal coat on the exterior of the roof slab. This coating shall be provided at the precasting plant. In addition, any top slab hand hole pockets or lifting holes, which are grouted in the field, shall received one coat of epoxy waterproofing seal coat after the grout has properly cured.
- All working drawings shall be on 24 in. by 36 in. sheets.
- The materials used for precast concrete box culverts shall conform to DDOT standards.
- Reinforcement steel shall conform to **AASHTO A615, Grade 60**. Welded deformed steel wire fabric, conforming to **AASHTO M221** and having a diameter of at least 3/8 in. may be substituted for deformed bars.

- Longitudinal tie bolts, where utilized, shall conform to the requirements of current **ASTM designation A307** and shall be hot-dip galvanized after fabrication, including threading in accordance with the requirements of current **ASTM A153**.
- Concrete for precast culverts shall conform to the DDOT standards, except that Coarse aggregate shall be washed gravel or broken stone of Argillite, Granite, Gneiss, Quartzite or Trap Rock, conforming to the requirements of DDOT standards and shall be graded as specified for standard size No. 57 or 67.
- Reference Subsection 23.3 for guidelines concerning beveling inner edges of the culvert entrance.

23.5 Rigid Frames

Rigid frames are three-sided concrete structures placed on pre-cast or cast-in-place footings with or without a paved invert. Rigid frame structures are used to span streams and seasonal waterways where a natural streambed is desirable and preferred for environmental reasons. Rigid frames may be cast-in-place or precast. Generally, the use of precast rigid frame sections can expedite construction to reduce the inconvenience to the traveling public. There are three types of rigid frames:

- Rectangular
- Trapezoidal
- Arch

Normally, the Department designs rectangular rigid frames. Proprietary designs for trapezoidal and arch rigid frames may be considered with the approval of the Bridge Design Engineer.

23.5.1 Design

This section applies to the design of rectangular rigid frames. Rigid frames are typically used for spans ranging from 12 ft. to 25 ft. Refer to Section 3, Loads and Load Distributions, and Section 8, Reinforced Concrete, in the **AASHTO Standard Specifications for Highway Bridges** for design requirements.

Typically, rigid frames support earth fills or hot-mix wearing surfaces, depending on the location and profile grade with respect to the top of the frame. A wearing surface is required for precast but not for cast-in-place rigid frames. When determining wall height for rigid frame structures, the following must be considered:

- Size of opening to meet the hydraulic requirements

- The economics of a higher frame versus the cost of fill
- Transportation costs of prefabricated elements
- Transportability of the elements
- Clearance for inspection, especially for flowing streams

A haunch is required where the wall and slab join. The minimum size is 6 by 6 in. Larger haunches, up to a maximum of 12 by 12 in., are permitted but must be reinforced. Depending on site conditions, rigid frames may be placed on:

- Cast-in-place spread footing
- Pile-supported cast-in-place footing

Holes are formed in precast frames to allow placement of tie rods to hold adjacent rigid frame sections together. Tie rods are not prestressed. Shear keys transfer shear between adjacent sections. The keys are sealed by filling the key with high strength, non-shrink, grout. Rigid frames should be damp proofed before backfilling.

23.5.2 Thickness

The minimum thickness of concrete for rigid frames components is 8 in.

23.6 Slab Culvert Bridges

Generally, slab bridge designs are not used for new bridges. They should be considered for locations where other bridge types cannot meet the required vertical clearance.

23.6.1 Design

Refer to Section 8, Reinforced Concrete, in the **AASHTO Standard Specifications for Highway Bridges,** for design criteria. Usually, slab bridges are used for short spans, 20 ft. or less. No provisions for expansion or contraction are needed for one-span slab bridges. Provisions for expansion and contraction are required for simple and continuous multi-span structures. Voided slabs may be used where reduced superstructure weight is needed. Drains must be provided for each void.

23.6.2 Thickness

The minimum thickness of concrete for slab bridge decks is 10 in.

23.7 Concrete Arches

Concrete arches are typically used to accommodate long span and low-rise site requirements. Typical concrete arch spans range from 30 to 50 ft. Concrete arches are used to span streams and seasonal waterways where a natural streambed is desirable and preferred for environmental or aesthetic reasons. All new concrete arches are precast. Extensions of existing arches may be cast-in-place.

23.7.1 Design

Refer to Section 8, Reinforced Concrete, and Section 17, Soil-Reinforced Concrete Structure Interaction Systems, in the **AASHTO Standard Specifications for Highway Bridges.** The design procedures in Section 8 apply for design of concrete arches where soil interaction is not considered. Soil interaction is considered only where the arch is poured monolithically with the footing. Two mats of steel are used in concrete arches. Concrete arches should be damp proofed before backfilling.

23.7.2 Thickness

The minimum thickness for concrete arches is 8 in.

23.8 Precast Proprietary Structures

Precast proprietary structures, may be proposed by contractors as alternatives to Department-prepared designs of rigid frame, or concrete arches. Proprietary structures may be considered on a case-by-case basis and must meet the following requirements for approval:

- Be designed using the same AASHTO methods used by the Department
- Allow structural rating using accepted methods
- Meet the specified minimum concrete strengths
- Provide the specified minimum steel reinforcing
- Furnish documentation of the structural strength of the structure including actual test results
- Provide documentation of long-term service to show durability

23.9 Concrete Cover

The minimum cover over reinforcing steel is 2 in. for all types of concrete culverts including reinforced concrete box, rigid frame, slab bridge, concrete arches and proprietary concrete structures.